# Effect of Spin Coating Conditions on the Inter-molecular Ordering and Performance of Organic Photovoltaic Materials

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## Introduction

Recent advances in organic electronics have led to remarkable progress in their functional applications, such as in organic light emitting diodes and field effect transistors, and also have shown a promising future in organic photovoltaics (OPVs). The performance and carrier transport properties of an OPV can be significantly improved by the ordering among its molecule constituents. Fully understanding the molecular ordering is therefore critical for the design and development of high performance OPVs that can be cost-effective, flexible, and lightweight alternatives to conventional inorganic devices. However, understanding the exact nature of such molecular ordering has been challenging due to the lack of experimental technique that are sensitive to the molecular ordering.

We proposed to use fluctuation electron microscope (FEM) to determine the molecular ordering of organic materials, and establish connections between the ordering and important properties of organic materials, which can significantly improve the performance of organic electronics.

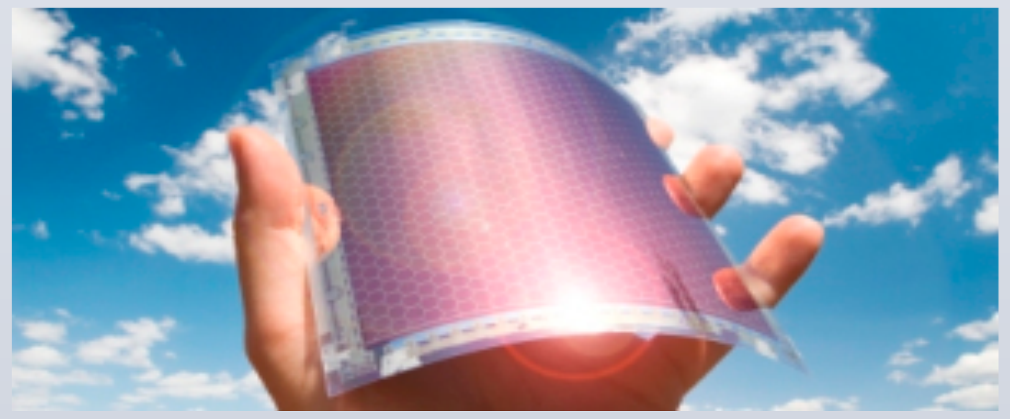


**Figure 1:** OPV

And for the observation method, FEM is a novel electron microscopy technique that is based on transmission electron microscopy (TEM).  FEM measures the nanoscale atomic ordering in disordered materials [4], and it can uncover the details of the nanoscale ordering, including the type, size, volume fraction, distribution, and networking, from any volume of the sample, regardless of orientation of the order.

## Objectives

The overall objective of this project is to establish the connections between the ordering and important properties of organic materials.

And the preliminary goal during this summer is to establish the standard preparation process of  samples, and one with best performance will be selected as a standard sample. Through the URO research program, we will also measure the electrical properties of the OPV films so that we can directly relate the property to the inter-molecular structure that we characterize using FEM.

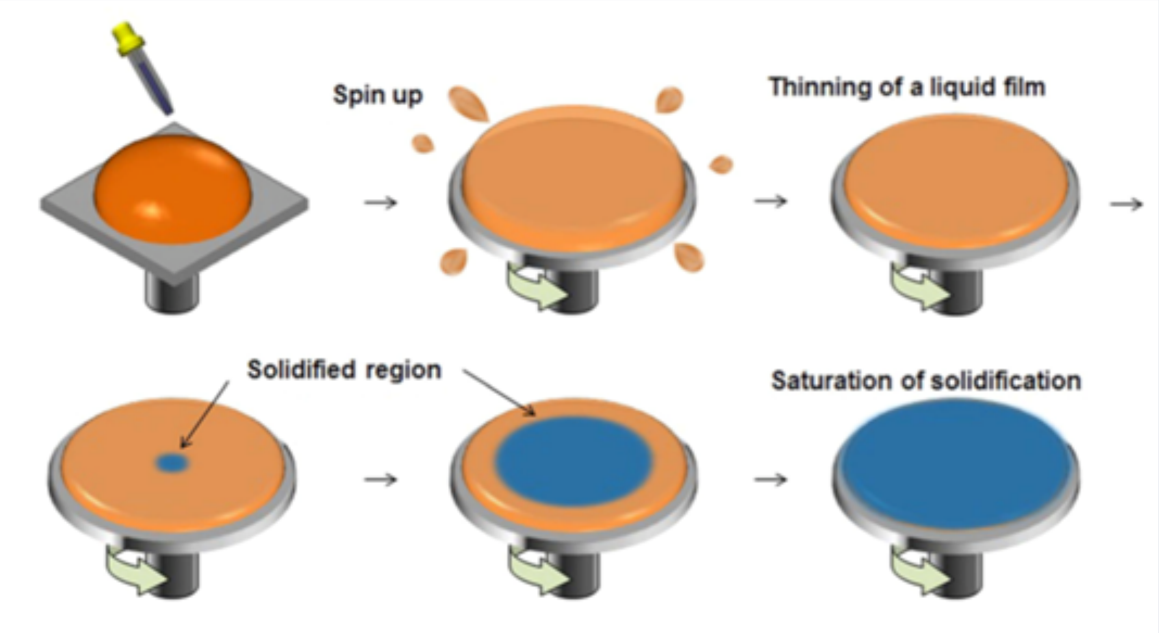
## Materials and Methods

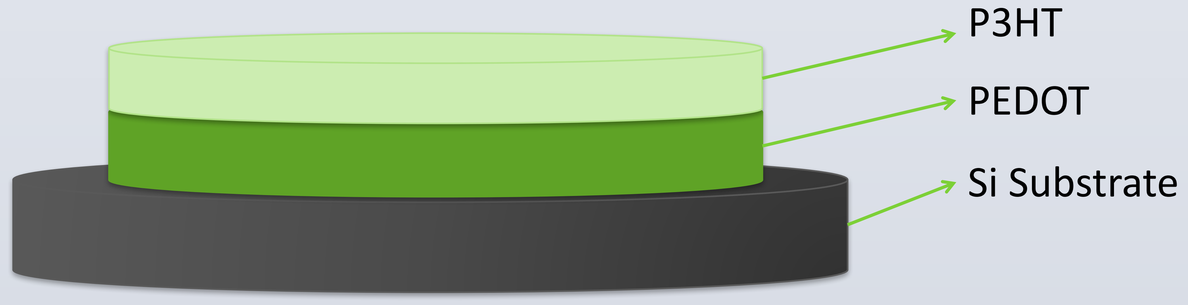
The material of interest in this project is P3HT, and it is a prototypical OPV with high PCE, and it has structural similarities to other common OPV molecules. The method used to fabricate samples is spin coating and a schematic is shown in the figure below.

P3HT is dissolved into chlorobenzene, because it has high boiling point (131 °C) and it allows a wide range of spinning times. Another solution called PEDOT is initially spin-coated onto the silicon substrate, because it has good water solubility and the team can peel off the P3HT film without causing damage to the structure by merging the sample into water later. Then P3HT solution is spin-coated on the top of PEDOT film. Finally, the P3HT film is peeled off and observed under FEM, electronic properties are also measured.

During the processing, different variables relating to the structure of material are controlled by the team, involving 1) substrate type (glass or silicon), 2) solution concentration, 3) initial heat-treatment of solution and substrate (time and temperature), 4)spin coating factors (steps, time and RPM), 4) finial heat-treatment (time and temperature).

Nanoscale microstructure of samples manufactured under different conditions can be detected through the observation under FEM. And by relating these structures to different processing variables, a connection between microstructure and manufacturing process can be established. And by relating these structure to different electrical properties they demonstrated, a connection between microstructure and properties can be established. Finally, one can make a component with desirable properties by controlling manufacturing variables by the two connections mentioned above.




The bottom layer of PEDOT will dissolve into water and leave the top layer floating in the water, and then the team can use TEM grid to scope the film.

**Figure 2:** Typical spin-coating process and the schematic of the sample in this project

## Preliminary Results

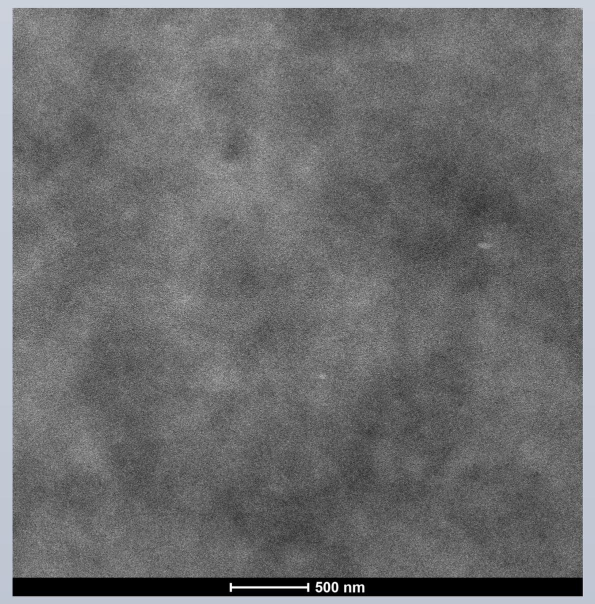



**Figure 3:** OPV original spin image Size (1000rpm)

It can be told from this image that P3HT is quite uniformly distributed, but some agglomeration can still be observed. This is caused by supersaturated solution and also non-equilibrium heat treatment.

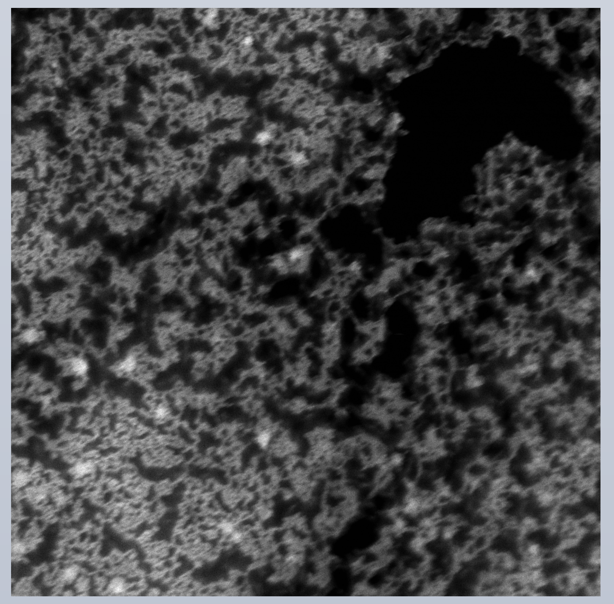


**Figure 4:** OPV fast image electron size (2000rpm)

Contamination is captured in this image, this is because carbon atoms in the TEM sample grid was excited by the light and gathered together at point of irradiation. Then, plasma clean is introduced to clean the sample.

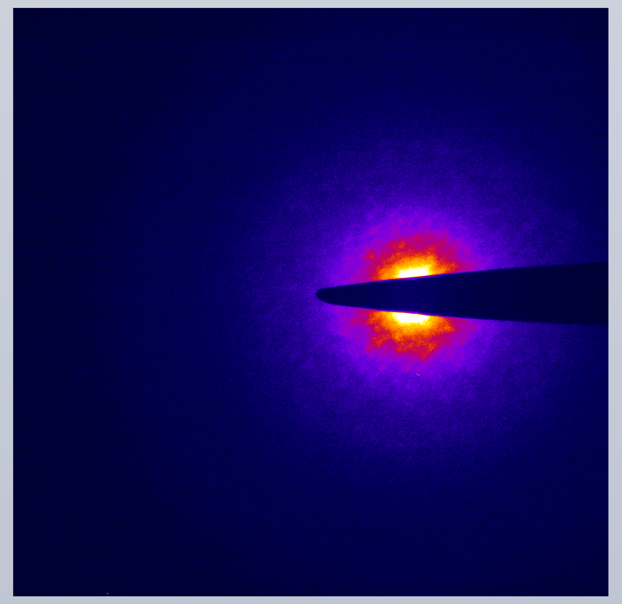


**Figure 5:** IPV fast spin image electron diffraction

This image demonstrate how the sample looks like under irradiation. The lighter the color, the higher the energy is. When all particles gather around the irradiation point, the sample will be thicker at that region, causing difficulty for observation.

## Conclusions

Based on the information collected, the team established the standard manufacturing process for the P3HT samples and one fabricated under 2000RPM. Except for the procedure mentioned in Methods part, plasma clean is introduced to get rid of the carbon atoms in TEM sample grid. However, it hasn't been proved that plasma clean doesn't have any effect on the structure of P3HT film. So, for the future goals, it's imperative to prove that plasma clean doesn't damage the P3HT sample or find an alternative treating method to get rid of carbon atoms; one promising method is heat-treatment in vacuum chamber. With this problem solved, the team will the team will move on to make samples under different conditions, and the structures and properties will be compared with the ones of standard sample, so that the team can establish the relationship between structure and different processing factors.

## References

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